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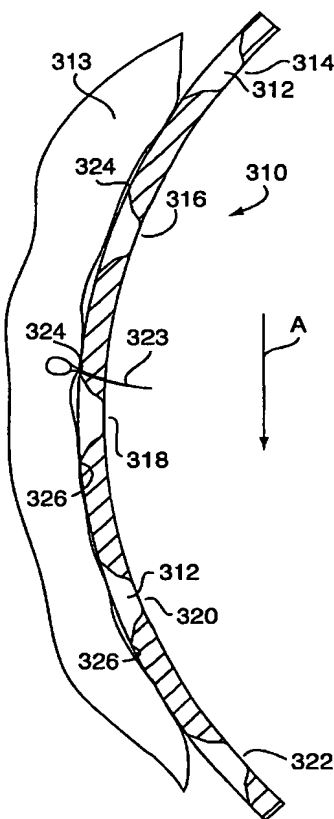
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[Continued on next page]

(54) Title: ZIRCONIA BASED BLADES AND FOILS FOR RAZORS AND A METHOD FOR PRODUCING SAME



(57) Abstract: Stabilized or partially stabilized zirconia paste may be screen printed onto hydrophilic film in the form of a mesh. On firing, this becomes a very sharp foil (10, 110, 210, 310) for electric razors with excellent wear characteristics. Stabilized or partially stabilized zirconia may also be screen printed onto a wettable plastic film then fired to produce low cost razor blades with an excellent edge. A curved razor blade (310) incorporating an array of holes (312), each of which has a knife edge periphery (324), offers greater cutting power and control of the skin surface than a single or double edge.

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ance Notes on Codes and Abbreviations" appearing at the begin-
ning of each regular issue of the PCT Gazette.*

ZIRCONIA BASED BLADES AND FOILS FOR RAZORS
AND A METHOD FOR PRODUCING SAME

CROSS REFERENCE TO RELATED APPLICATIONS

5 This application claims the benefit of British Provisional Application No. 0222712.2 filed on October 1, 2002 entitled "Zirconia Razor Foil"; British Provisional Application No. 0223567.9 filed on October 10, 2002 entitled "Ceramic Razor Blades"; and British Provisional Application No. 0223882.2 filed on October 16, 2002 entitled "Perforated Razor Blade"; the disclosures of which are incorporated by
10 reference herein in their entirety.

FIELD OF THE INVENTION

 This invention relates generally to blades and foils for razors, and more particularly relates to zirconia based blades and foils for razors, as well as methods
15 for producing same.

BACKGROUND OF THE INVENTION

 Electric razors with cutting foils and wet shave razors with cutting blades have been in use for many decades. With respect to electric razors, they comprise
20 a pierced foil and cutter. The foil is generally electroformed from nickel, which provides a very sharp edge but of limited hardness. Electric razor foils are generally made by electroforming nickel. This is a relatively expensive process and the hardness of the resulting nickel cutting edges is not that high.

 With respect to wet shave razors, the razor blades traditionally have a
25 straight cutting edge that extends the length of the razor head. Safety razors have guards to control the position of the skin with respect to the cutting edge, so that the cutting edge rides over the skin but cuts protruding hair. Such razor blades have traditionally been made from high quality carbon steel. The innovation of using stainless steel has been fraught with the difficulty of forming and holding an
30 ultra sharp edge. Ground ceramic razor blades tend to have a ragged microstructure rather than rounded, and consequently dig into skin rather than sliding over it.

Accordingly, it is a general object of the present invention to provide zirconia based blades and foils, and methods of fabrication thereof, that overcome the above-identified drawbacks of prior razors.

SUMMARY OF THE INVENTION

The present invention resides in a method of fabricating a foil for an electric razor. A substrate is provided including a combustible surface. A foil plan form is generated on the combustible surface with a zirconia based ink such that flow of the ink under surface tension forces generates sharp edges to the foil. The foil plan form is fired to burn away the combustible surface such that zirconia forms a durable foil that maintains sharpness over repeated use. The zirconia based ink can include partially stabilized or fully stabilized zirconia. The printing of the foil plan form can be accomplished by either screen printing or vacuum forming. The combustible surface can include, for example, a plastic film of high surface finish, and is preferably hydrophilic.

The present invention also resides in a method of fabricating a blade for a wet shave razor. A substrate is provided including a combustible surface. A zirconia based ink is generated on the combustible surface such that the ink wets the substrate and edges of the ink slightly to form a plurality of sharply pointed meniscus to serve as cutting surfaces. The ink is fired to burn away the combustible surface and to harden a rounded, sharp edge on the plurality of meniscus. Preferably, the sharp edges of the meniscus have an edge radius of about 50 nanometers or less.

The present invention further resides in a blade for a wet shave razor that is bidirectional and comprises a substrate curved along a direction of blade movement to conform to a contour of the skin of a user. The blade substrate defines a plurality of holes each having a periphery. A leading portion of the holes in the direction of blade movement serves as a guard, and a trailing portion of the holes serves as a cutting edge. Preferably, the substrate includes partially stabilized or fully stabilized zirconia. The holes are arranged in an array that can be either even or staggered. The shape of the holes can be, for example, rectangular or diamond-shaped.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a top plan view of a razor blade substrate defining an array of rectangular slots serving as cutting edges in accordance with the present invention.

5 FIG. 1B is a top plan view of a razor blade substrate defining an array of staggered rectangular slots serving as cutting edges in accordance with another embodiment of the present invention.

FIG. 1C is a top plan view of a razor blade substrate defining an array of diamond-shaped slots serving as cutting edges in accordance with a further embodiment of the present invention.

10 FIG. 2 is an elevational, cross-sectional view of the razor blade of FIG. 1 showing a curved contour of the blade in contact with the skin of a user.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

15 In accordance with the present invention, an electric razor foil can be made from zirconia ceramic. The zirconia may be partially or fully stabilized. The foil may be fabricated by screen printing the foil plan form onto a hydrophilic surface with a zirconia based ink, such that flow of the ink under surface tension forces generates very sharp edges to the ceramic foil. The planar hydrophilic surface may be combustible so that it vanishes during firing. The surface is preferably a plastic
20 film of good surface finish. The foil network may be biaxially extensible to conform to the skin. The cutter may also be in the form of a zirconia foil. The zirconia print and plastic film may be formed prior to firing. Vacuum forming may be appropriate. Appropriate binders and plasticisers in the zirconia ink may stop cracking of the ceramic print during the forming process.

25 Partially stabilized zirconia has the hardness and toughness of tool steel. It has excellent wear characteristics and takes a very keen edge. While it is much more expensive, the quantity in a razor foil is minimal and it may be fabricated more cheaply than electroforming.

30 A razor foil pattern may be precisely screen printed onto a plastic film with a zirconia ink. If the film is slightly hydrophilic it may be arranged, by controlling the ink properties, such that the edges of the print may run slightly under the influence of surface tension forces to provide an extremely sharp edge. Even a low cost plastic film may have a surface finish approaching optical quality and the zirconia print will accurately reproduce this.

The printed plastic film may be fired in the conventional manner. The plastic will burn away at a low temperature and the zirconia will form a very thin foil of extreme toughness. It will maintain its sharpness for a long time.

5 The foil pattern can be printed in a manner that permits biaxial extension to follow the contours of the skin. A cutter in foil form can also be fabricated which will follow the outer foil and provide a flexible cutting surface.

10 The printed plastic may be vacuum formed if desired. This permits the forming of the profiled cutters used in current multi head shavers. The form may also be exploited to assist with maintaining dimensional stability during the firing process.

15 Further in accordance with the present invention, razor blades can be fabricated from a ceramic ink that is screen printed on a combustible surface and then fired. The ceramic is preferably stabilized or partially stabilized zirconia. The combustible surface is preferably a plastic film of high surface finish. The ink vehicle and combustible surface may be so chosen that the ink wets the combustible surface.

20 Stabilized zirconia forms exceptional cutting blades. It is extremely strong, tough and hard. In thin sheets it may be very pliable. It has been discovered to be an excellent medium for razor blade fabrication. The raw material is very expensive compared with steel and is expensive to diamond machine. Cutting edges in zirconia are conventionally created by diamond machining, but this process produces ragged edges on a micro-scale which tend to dig into skin rather than slide over it. This, of course, is disastrous in a razor blade.

25 Screen printing of ceramic inks is a well known mass production technique in hybrid electronics. This produces a thin film of very finely controlled thickness at very low cost. The ink comprises very finely powdered ceramic in a binder and solvent. It is possible to choose the composition of ink such that it wets the substrate and the edges of the print flow slightly to form a sharply pointed meniscus. On firing, the substrate may burn away and the meniscus will form a
30 very sharp edge. The firing process causes the finely powdered grains to sinter into a solid mass. This process may be exploited to form an edge to the blade which is rounded on a microscale. With modern milling techniques, the powder particle size may be some tens of nanometers. It is therefore possible to organize the firing to produce a blade with an edge radius of about 50 nanometers or less.

The ceramic will take the surface finish of the substrate on the printed side, which may approach optical quality for many plastic films. If this is the side that faces the skin, a very smooth blade will result. Screen printing produces very thin layers with excellent reproducibility. Zirconia blades as thin as about 0.025 mm are feasible. By using thin blades of minimum width, blade costs of a fraction of a penny are feasible.

This fabrication technique offers the advantages of large scale mass coupled with low materials cost and no finishing processes.

Further in accordance with the present invention, a metallic or ceramic razor blade can be curved and define a plurality of holes or slots, some or all of which incorporate a cutting edge as part or all of their periphery. With reference to FIG. 1A, for example, a razor blade is indicated generally by the reference number 10. The blade 10 defines a plurality of holes or rectangular slots 12 that preferably form an array. As shown in FIG. 1A, the array of slots 12 includes five columns 14, 16, 18, 20 and 22. However, the array can include a fewer or greater number of columns than that illustrated without departing from the scope of the present invention. A portion of the periphery of the slots 12 serve as cutting edges that are well protected within the slots. As a result, the edge of the blade is no longer in need of careful protection.

With respect to the direction of blade movement during a shaving operation as indicated by the arrow A, the longer edges of the rectangular slots 12 are trailing edges 24 and leading edges 26. The blade 10 further defines interconnecting spokes 28 between shorter edges 30 of the rectangular slots 12 for enhancing the rigidity of the blade. A periphery 32 of the blade 10 may be used to retain the blade in a razor.

The leading edges 26 serve as a guard, and the trailing edges 24 serve as the cutting edge. However, the blade 10 can be used in a direction opposite to that indicated by the arrow A. When used in such opposite direction, the edges 24 are the leading edges serving as the guard, and the edges 26 are the trailing edges serving as the cutting edges.

Turning to FIG. 1B, a blade in accordance with another embodiment of the present invention is indicated generally by the reference number 110. Like elements with those shown in FIG. 1A are indicated by like reference numbers preceded by "1". The blade 110 defines a plurality of holes or staggered

rectangular slots 112 that form an array. As shown in FIG. 1B, the array of slots 112 includes five columns 114, 116, 118, 120 and 122. The slots in adjacent columns are positioned in staggered relationship to one another to provide a consistent cutting surface along a direction of the blade transverse to that of the direction of movement.

Similar to the previous embodiment, a portion of the periphery of the slots 112 serve as cutting edges. With respect to the direction of blade movement during a shaving operation as indicated by the arrow A, the longer edges of the rectangular slots 112 are trailing edges 124 and leading edges 126. The blade 110 further defines interconnecting spokes 128 between shorter edges 130 of the rectangular slots 112 for enhancing the rigidity of the blade. A periphery 132 of the blade 110 may be used to retain the blade in a razor.

The leading edges 126 serve as a guard, and the trailing edges 124 serve as the cutting edge. However, the blade 110 can be used in a direction opposite to that indicated by the arrow A. When used in such opposite direction, the edges 124 are the leading edges serving as the guard, and the edges 126 are the trailing edges serving as the cutting edges.

Turning to FIG. 1C, a blade in accordance with a further embodiment of the present invention is indicated generally by the reference number 210. Like elements with those shown in the previous embodiments are indicated by like reference numbers preceded by "2". The blade 210 defines a plurality of holes or staggered diamond-shaped slots 212 that form an array. The blade 210 also preferably defines partial or half-diamond-shaped slots 213 at ends of the array for even distribution of cutting surfaces between sides of the blade. As shown in FIG. 1C, the array of slots 212 includes five columns 214, 216, 218, 220 and 222. The slots in adjacent columns are positioned in staggered relationship to one another to provide a consistent cutting surface along a direction of the blade transverse to that of the direction of movement.

Similar to the previous embodiments, portions of the periphery of the slots 212 serve as cutting edges. With respect to the direction of blade movement during a shaving operation as indicated by the arrow A, the diamond-shaped slots 212 each include trailing edges 224, 225 and leading edges 226, 227. A periphery 232 of the blade 210 may be used to retain the blade in a razor.

The leading edges 226, 227 serve as a guard, and the trailing edges 224, 225 serve as the cutting edge. However, the blade 210 can be used in a direction opposite to that indicated by the arrow A. When used in such opposite direction, the edges 224, 225 are the leading edges serving as the guard, and the edges 226, 227 are the trailing edges serving as the cutting edges.

With reference to FIG. 2, a blade in accordance with the present invention may have an overall curvature to expose different angles of blade to the skin. A curved blade 310 defines an array of holes or slots 312 in contact with skin 313 of a user during a shaving operation. As shown in FIG. 2, the array of slots 312 includes five columns 314, 316, 318, 320 and 322. With respect to the direction of blade movement during a shaving operation as indicated by the arrow A, a hair 323 is shown being cut by a trailing or cutting edge 324 of one of the holes 312. The curvature and flexibility of the blade 310 may be predetermined to offer the maximum ability to follow skin contours. Several cutting edges 324 may be in contact with the skin simultaneously. The leading edges 326 of the holes or slots 312 control the access of the skin 313 to the cutting edges 324 of the hole 312. The blade may be formed from metal by electroforming or by grinding away dimples in a planar shim. The blade may also be formed by screen printing ceramic ink as an array of holes, and then firing the print. The rheology of the ink may be arranged so that the flow of the periphery of the wet print may form a meniscus which becomes a polished razor edge on firing. The ceramic is preferably partially stabilized or fully stabilized zirconia ceramic. The ceramic may also be ground and polished after firing if desired.

Razor blades traditionally have a straight cutting edge. An array of holes with cutting edges around their periphery in accordance with the present invention provides a longer cutting edge per square millimeter of blade and a tighter control of the angle at which the skin meets the blade. This results in a more rapid and closer shave with less chance of nicking the skin.

In a metal blade, such an array may be made by electroforming. Electroforming is relatively expensive for disposable blades, however, and nickel, which is the only practical metal for this technique, is not exceptionally hard. An alternative is to form an array of indentations in a planar metal shim, and then to grind away the raised bumps to create holes surrounded by a cutting edge.

A better process is to screen print the blade pattern with partially stabilized zirconia ink. If the rheology of the ink and the nature of the substrate are carefully chosen, the edges of the print flow to create a wetting meniscus. On firing, this meniscus naturally creates a polished razor edge.

5 As will be recognized by those of ordinary skill in the pertinent art, numerous modifications and substitutions may be made to the above-described embodiment of the present invention without departing from the scope of the invention. Accordingly, the preceding portion of this specification is to be taken in an illustrative, as opposed to a limiting sense.

WHAT IS CLAIMED IS:

1. A method of fabricating a foil for an electric razor, comprising the steps of:
 - providing a substrate including a combustible surface;
 - generating a foil plan form onto the combustible surface with a zirconia
 - 5 based ink such that flow of the ink under surface tension forces generates sharp edges to the foil; and
 - firing the foil plan form to burn away the combustible surface such that zirconia forms a durable foil that maintains sharpness over repeated use.
2. A method as defined in claim 1, wherein the step of generating includes screen printing the foil plan form onto the combustible surface.
3. A method as defined in claim 1, wherein the step of generating includes vacuum forming the foil plan form onto the combustible surface.
4. A method as defined in claim 1, wherein the zirconia based ink includes partially stabilized zirconia.
5. A method as defined in claim 1, wherein the zirconia based ink includes fully stabilized zirconia.
6. A method as defined in claim 1, wherein the combustible surface is hydrophilic.
7. A method as defined in claim 1, wherein the combustible surface is a plastic film of high surface finish.

8. A method of fabricating a blade for a wet shave razor, comprising the steps of:

providing a substrate including a combustible surface;

5 generating a zirconia based ink onto the combustible surface such that the ink wets the substrate and edges of the ink slightly to form a plurality of sharply pointed meniscus to serve as cutting surfaces; and

firing the ink to burn away the combustible surface and to harden a rounded, sharp edge on the plurality of meniscus.

9. A method as defined in claim 8, wherein the step of generating includes screen printing the zirconia based ink onto the combustible surface.

10. A method as defined in claim 8, wherein the zirconia based ink includes partially stabilized zirconia.

11. A method as defined in claim 8, wherein the zirconia based ink includes fully stabilized zirconia.

12. A method as defined in claim 8, wherein the combustible surface is hydrophilic.

13. A method as defined in claim 8, wherein the combustible surface is a plastic film of high surface finish.

14. A method as defined in claim 8, wherein the sharp edges of the meniscus have an edge radius of about 50 nanometers or less.

15. A blade for a wet shave razor comprising a substrate curved along a direction of blade movement to conform to a contour of the skin of a user, the blade substrate defining a plurality of holes each having a periphery, a leading portion of the holes in the direction of blade movement serving as a guard, and a
5 trailing portion of the holes serving as a cutting edge.

16. A blade for a wet shave razor as defined in claim 15, wherein the substrate includes zirconia.

17. A blade for a wet shave razor as defined in claim 15, wherein the zirconia is partially stabilized.

18. A blade for a wet shave razor as defined in claim 15, wherein the zirconia is fully stabilized.

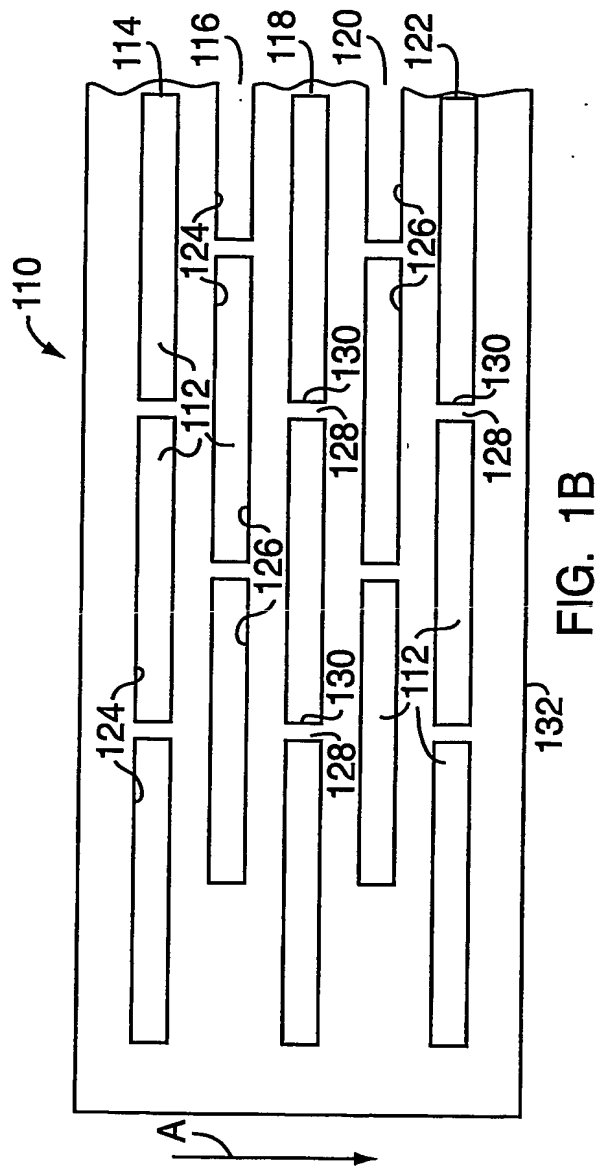
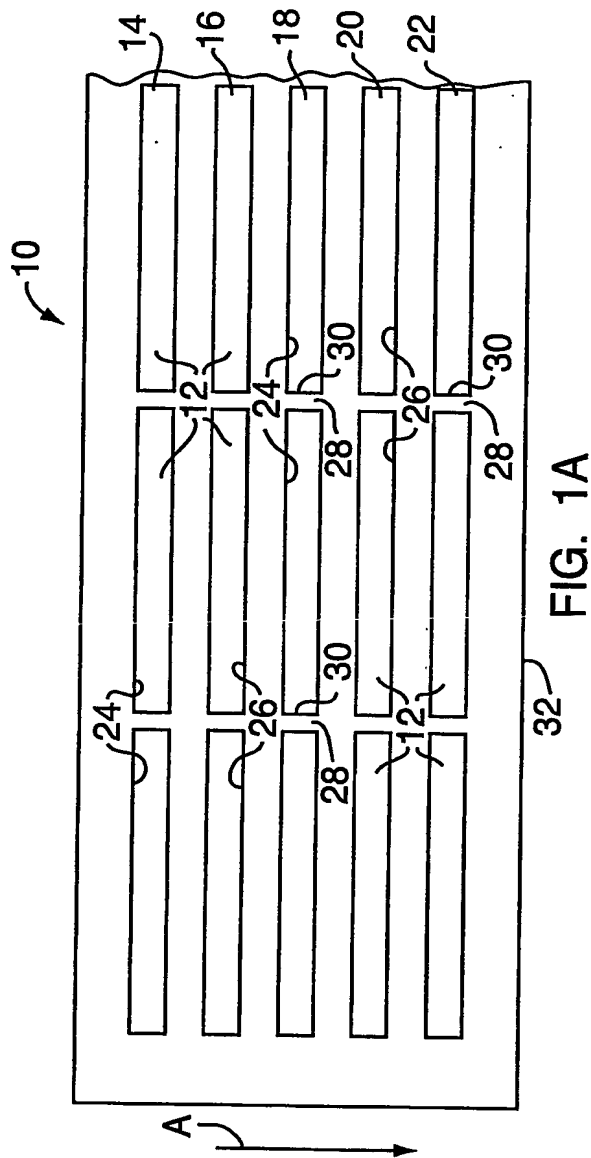
19. A blade for a wet shave razor as defined in claim 15, wherein each of the holes is generally rectangular.

20. A blade for a wet shave razor as defined in claim 15, wherein each of the holes is generally diamond-shaped or partially diamond-shaped.

21. A blade for a wet shave razor as defined in claim 15, wherein the holes defined by the substrate are arranged in an array.

22. A blade for a wet shave razor as defined in claim 21, wherein the array includes columns along a direction of blade movement, and wherein adjacent columns are staggered in relation to one another.

23. A blade for a wet shave razor as defined in claim 15, wherein the portion of the holes serving as a guard become the portion of the holes serving as a cutting edge when the direction of blade movement is reversed, and wherein the portion of the holes serving as a cutting edge becomes the portion of the holes serving as a guard when the direction of blade movement is reversed.



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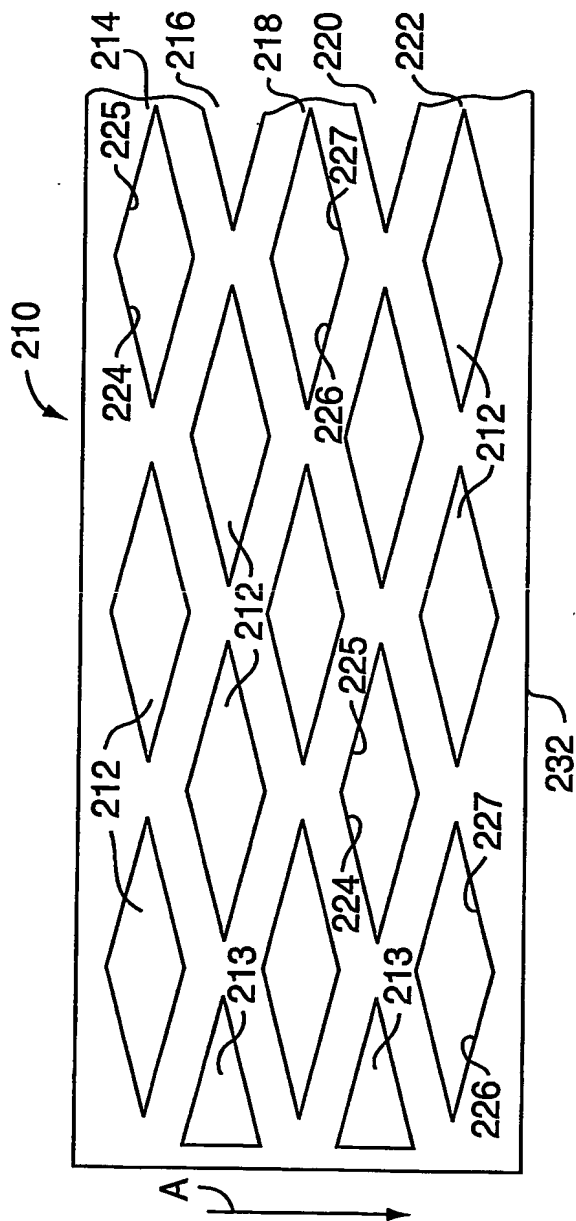


FIG. 1C

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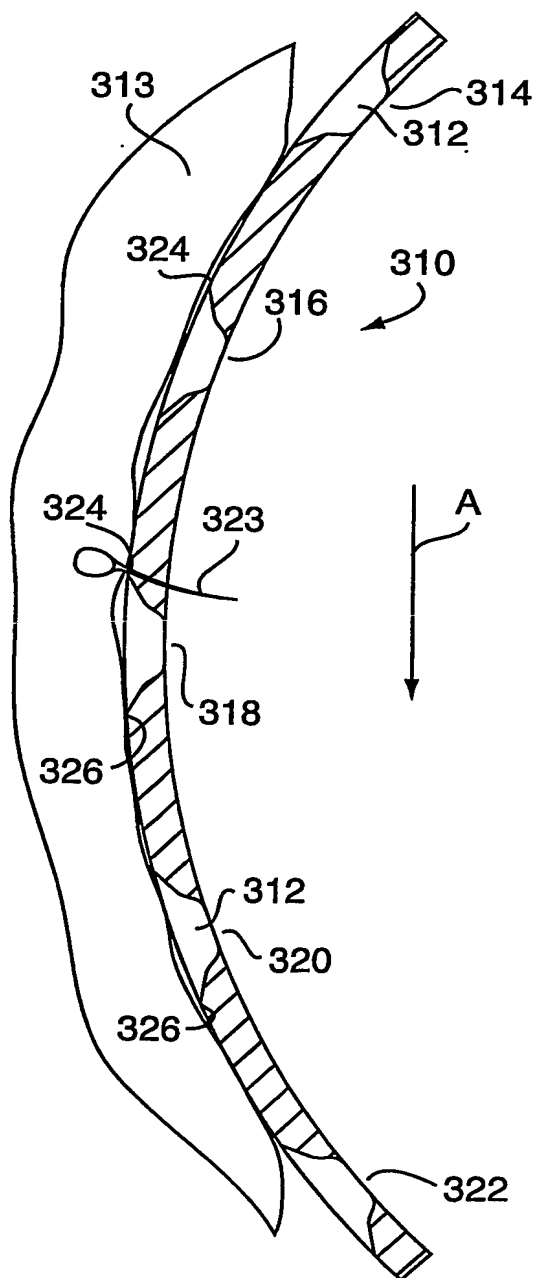


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US03/30958

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : B26B 21/56; B32B 1/00

US CL : 30/346.54; 76/104.1

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 30/346.54; 76/104.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,018,274 A (TROTTE) 28 May 1991 (28.05.1991), see entire document	15-23
A,E	US 2003/0063155 A1 (NAKAO et al.) 03 April 2003 (03.04.2003)	1-14

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

25 February 2004 (25.02.2004)

Date of mailing of the international search report

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Name and mailing address of the ISA/US

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INTERNATIONAL SEARCH REPORT

Int ional application No.

PCT/US03/30958

Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claim Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claim Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
Please See Continuation Sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐
☒

- The additional search fees were accompanied by the applicant's protest.
No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

PCT/US03

8

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claim(s) 1-14, drawn to a method of making a blade.

Group II, claim(s) 15-23, drawn to a razor blade.

The inventions listed as Groups I and II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: the method includes details to the combustible substrate and flowing ink while the blade includes details to the cutting edges and guard edges.

Continuation of B. FIELDS SEARCHED Item 3:

APS

terms: ceramic ink, zirconia, razor